STUDY ON DISSIMILAR ALUMINIUM ALLOYS OF AA7075 AND AA6061 USING FRICTION STIR WELDING

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ABSTRACT

The present study focuses on the effects of material position and tool rotational speed on tensile strength of dissimilar aluminium alloys welded of AA7071 and AA6061 with thickness of 2.0 mm using conventional milling machine. Ten joints were produced by varying tool rotational speeds and by changing the fixed position of material in advancing and retreating side. The result shows that the rotational speed and material position influenced the tensile strength value of dissimilar welds. The welded joints showed maximum tensile strength of 207 MPa when aluminium alloys of AA6061 were placed in advancing side at 1000 rpm, while minimum tensile strength value of 160 MPa were obtained at 1000 rpm when AA7075 was placed in advancing side except for rotational speed beyond 1200 rpm that shows increasing in tensile strength values.

Keywords: Friction stir welding; rotational speeds; aluminium alloys; tensile strength.

INTRODUCTION

Friction stir welding (FSW) that was invented at The Welding Institute (TWI) is a novel solid-state welding technology that has been widely used for joining alloys and metals. FSW process performs below the solidus temperature of the metals being joined and the used of any filler material is not required. During the FSW process, a non-consumable rotating tool with a pin and shoulder that provides 'stir' action is inserted into the abutting edges of plates to be joined and will traverse along the joint line. The rotating tool moves along the weld line and develops frictional heating of the material, causing it to plasticize where it cools and consolidates to produce high integrity weld (Dinaharan et al., 2012; Mishra & Ma, 2005; Pumchan, 2011).

Nowadays, the automotive industry demand for vehicles that has greater performance, energy savings and environmental preservations that also helps in cost reduction. Since reducing the weight is one of the efficient measures, the combination of dissimilar grades of aluminium alloy has been increasing in fabricating vehicles (Amancio-Filho et al. 2008). This effort is being carried out by substitution of light materials especially aluminium. However, a sound joint is difficult to be produced so far by the conventional fusion welding method alone and FSW technology is chosen as it appears as the promising techniques that produce high weld efficiency and its capability to joint materials that is usually difficult to weld by using conventional welding.references

Due to high demand of joining dissimilar materials for new structures or parts with mixed materials properties especially in the automotive industry, aluminium alloy of AA6061 and AA7075 were selected for FSW process in this study. AA6061 alloys are high strength, high corrosion resistance and lightweight aluminium that have high ductility and toughness.Meanwhile, AA7075 exhibit super high strength that has been used extensively in aircraft component and other highly stressed applications. Both materials of AA6061 series and AA7075 series are extensively employed in marine fittings, automobiles and aircraft applications (Rajakumar, Muralidharan & Balasubramanian, 2011).

Some successful studies on dissimilar materials shows the improvement of the joint made by Khodir and Shibayanagi (2008) on friction stir welding of dissimilar AA2024 and AA7075 aluminium alloys by varying the welding speed and fixed location of base metals. It is found that the mechanical properties of the welded joint is improved at welding speed of 1.67 mm/s and when placing AA2024 on the advancing side. Ravikumar et al.(2013) studied dissimilar friction stir welded AA7075-T651 and AA6061-T651 butt joint on macro and micro structural characteristics which presents the better mixing of both materials and good strength of weld at 900 rpm, 90mm/min with taper cylindrical threaded tool. Research done by Ghosh et al.(2010) on optimization of friction stir welding parameters for A356 and AA6061 by varying the tool rotational speeds of 1000-1400 rpm and traversing speeds of 80-240 mm/min that is responsible for the change in total heat input and cooling rate during FSW process. Joint improvement of the weld strength is produced at lowest tool traversing and rotational speed which more than 98 % of 6061 alloy. In addition, Filho et al.(2008) have found the defect-free friction stir welds of dissimilar alloys system of AA2024-T351 and AA6056-T4 in the preliminary study on the microstructure and mechanical properties in aircraft alloys. Furthermore, tensile tests have shown reasonable joint efficiencies in terms of ultimate tensile strength which produces around 56% of the 2024-T351 and about 90% of the 6056-T4 alloy strength. Li and Shen (2012) has proved that improved weld strength of dissimilar welded AA6063 and AA5052 is achieved by using a further designed tool of quench hardening W9Mo3Cr4V type with some geometric improvements. Other than that, the studies show that the material position at the retreating side benefited the formation of the weld and the interfacial gap between lap materials is reduced in the feasibility research on FSW process of the new-typed lap-butt joint of dissimilar Al alloys. Thus, to incorporate these dissimilar aluminium materials joint, the feasibility friction stir welding parameters is important in order to produce better bond strength(Amancio-Filho et al., 2008; Ghosh et al., 2010; Khodir & Shibayanagi, 2008; Li & Shen, 2012; Ravikumar, Rao & Pranesh, 2013). It is proved that past researchers show good findings in dissimilar FSW of aluminium alloys, and has shown enormous potential to be implemented in various industries. Unfortunately, limited study has been conducted between AA7075 and AA6061, despite the vast industry applications for both materials.

In this study, an attempt is made to join 2.0 mm plates of AA7075 and AA6061 using FSW and investigate the effects of rotational speed and base material positioning on the tensile properties.

MATERIALS AND METHODS

Materials

Aluminium alloys AA7075 and AA6061 plates of size 100 mm× 50 mm×2 mm were used in this study and clamped rigidly on the backing plate for welding. Table 1 and

Table 2 presented the chemical composition and physical properties of AA7075 and AA6061.

Table 1. Chemical compositions of AA6061 and AA7075 alloys (wt %).

Alloy	Zn	Mg	Cu	Mn	Si	Fe	Ti	Cr	Al
AA6061	0.25	0.8-1.2	0.15-0.4	0.15	0.4-0.8	0.7	0.15	0.04-0.35	Bal.
AA7075	5.1-6.1	2.1-2.9	1.2-2.0	0.3	0.4	0.5	0.2	0.18-0.28	Bal.

Table 2. Physical properties of AA6061 and AA7075 alloys.

Properties	**Melting point**	**Solidus temperature**	**Thermal conductivity (W/m-K)**	**Tensile strength (MPa)/ Hardness**
AA6061	652 °C	582 °C	167	353 /96Hv
AA7075	635°C	477°C	130	572 /175Hv

Experimental Procedure

Type of the tool used was cylindrical plain type from H13 steel and Figure 1 shows the tool design that was used in FSW process. Table 3 shows the tool dimension of H13 steel. As received H13 tool material of 20 mm diameter rod were processed on lathe machine according to specified dimensions.

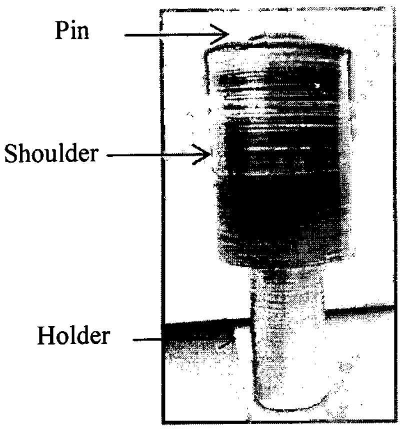


Figure 1. FSW tool.

Table 3. Tool dimensions.

Pin	Values (mm)
Pin length,	1.7
Tool shoulder diameter, D	18
Pin diameter,d	6
Holder diameter	8
Holder length	36
Shoulder length	10

FSW process was carried out on the VMM3917 Partner vertical milling machine with butt joint configuration. Welding speed and tool tilt angle were kept constant at 100 mm/min and 3° angle respectively. The variables parameters are rotational speed (rpm) and the material position. The process was performed by using two separated groups, Group A and Group B with five consecutive values of rotational speed; 800

rpm, 900 rpm, 1000 rpm 1200 rpm and 1400 rpm and changing the fixed position of materials for each group as shown in Table 4.

Table 4. Welding plan of dissimilar joints.

Group (A/B)	Tool rotational speed (rpm)	Material at Advancing side (AS)	Sample label
A	800	AA6061	A
A	800	AA7075	C
A	900	AA6061	E
A	900	AA7075	G
A	1000	AA6061	I
B	1000	AA7075	B
B	1200	AA6061	D
B	1200	AA7075	F
B	1400	AA6061	H
B	1400	AA7075	J

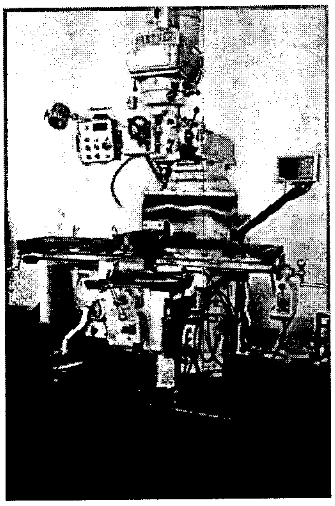


Figure 2. Milling machine (VMM3917 Partner).

All 10 joints were welded with the selected parameters range with different fixed position of material to evaluate its tensile characteristics. Tensile strength of welded specimen was investigated using tensile test machine, INSTRON Bluehill machine. The dimension for the tensile specimen is according to ASTM E8 standard. Three tensile specimens were prepared for each weldment and average ultimate tensile strength (UTS) value was taken.

RESULTS AND DISCUSSION

Surface Weld Appearance

Figure 3 shows the FSW welded samples with different rotational speed of 800 rpm, 900 rpm, 1000 rpm, 1200 rpm, and 1400 rpm, respectively. The best weld appearance is produced at 1000 rpm when AA6061 was positioned at advancing side as the joint surface was clear from severe FSW defects and has a smooth surface. Defect of ribbon flash were found at some welded specimens from sample A, D, G, I and J. Ribbon flash is an excessive expulsion of material on the top surface leaving a ribbonlike effect which is occurred due to excessive forge load or due to excessively hot weld. Other defects that occured in FSW process are burr and surface galling that can be seen from most of the samples. These defects was resulted from sticking of metal to pin tool and from excessively hot weld. Some severe defects that occured in FSW specimens can cause degrading in its mechanical properties (Arbegast & William, 2003).

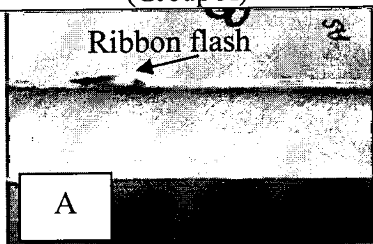
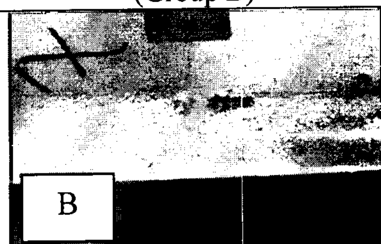
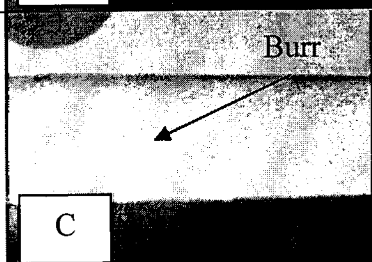
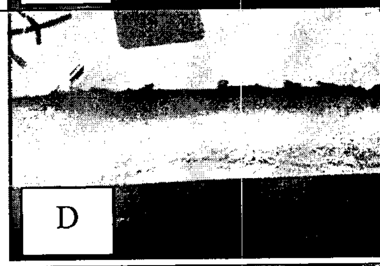
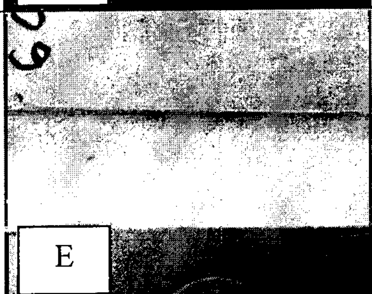
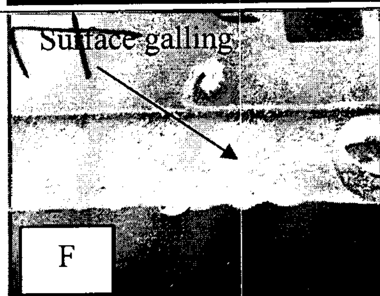
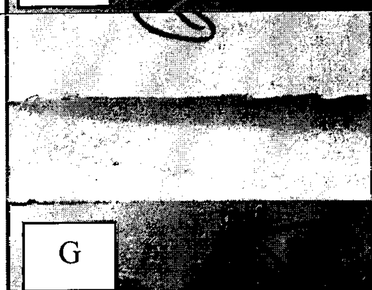
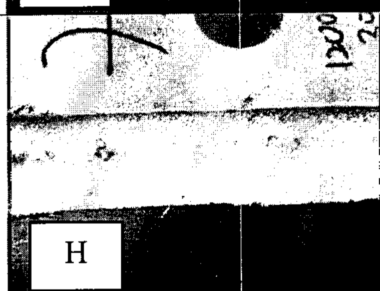
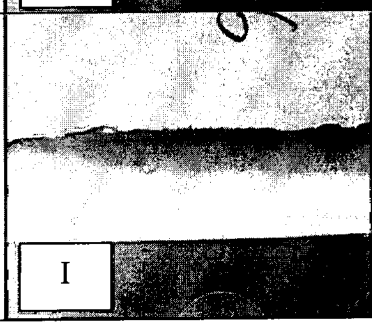
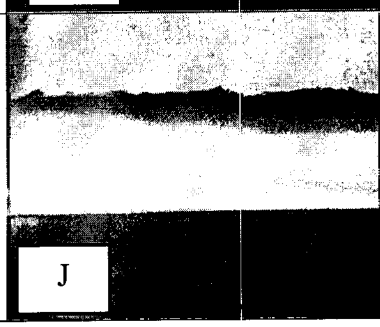
Rotational speed (rpm)	AA6061 at advancing side (Group A)	AA7075 at advancing side (Group B)
800		
900		
1000		
1200		
1400		

Figure 3. Weld appearance (top view) for welded specimens.

The weld appearance is affected by the heat input being supplied from tool rotational speeds during FSW joints. From Figure 3(F), defect that occurred is surface galling that is due to the sticking of material to tool pin and low travelling speed. These defects can reduce the strength of the weld joints and can be prevented by increasing the axial force pressure and increasing the rotational speed so that the stirring action between materials will smooth the formation of the flow arm at weld line (Li & Shen, 2012).

Tensile Properties

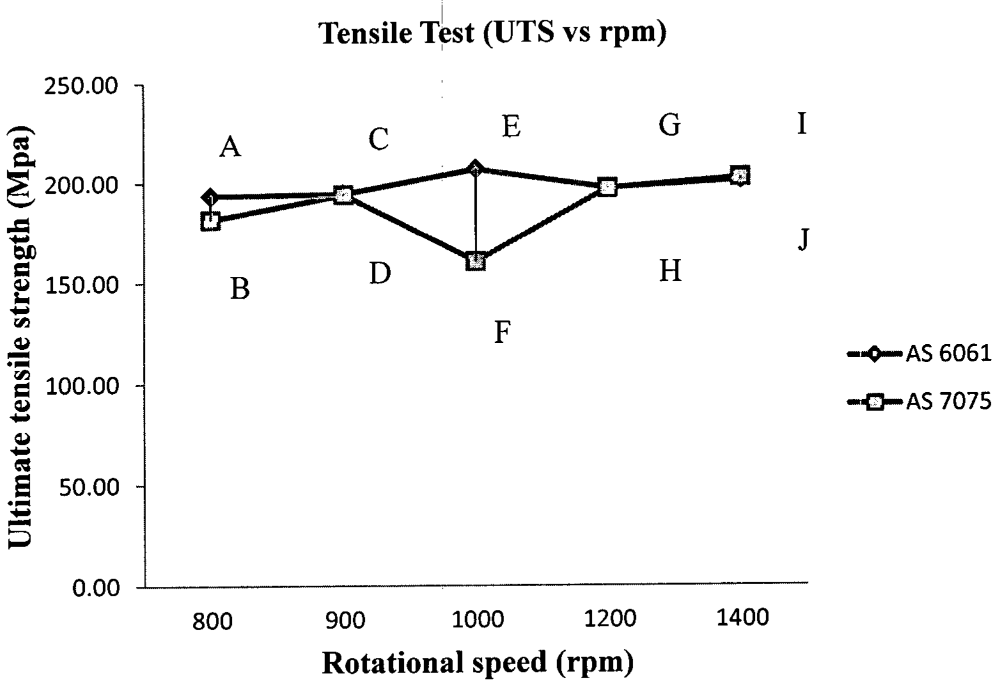


Figure 4. Tensile strength of dissimilar aluminium alloys of AA6061 and AA7075 joints.

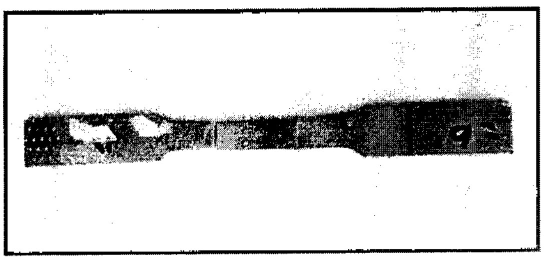


Figure 5. Example of specimen for tensile Test (sample F).

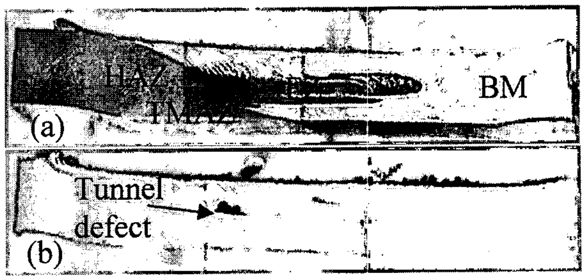


Figure 6. Weld cross section area for 1000 rpm (a) sample E; (b) sample F.

Tensile test was conducted for dissimilar aluminium alloys joining. Figure 4 presents the tensile strength result of the dissimilar aluminium weldments. Figure 5 shows the example of fractured specimen for tensile test from sample F. From the graph, it can be observed that sample E has maximum ultimate tensile strength (UTS) of 206.65 MPa at 1000 rpm and when AA6061 was positioned in advancing side. Sample F exhibit lowest UTS at 160.28 MPa when AA7075 was positioned in advancing side at

1000 rpm. From the overall result of Group A (AA6061 at advancing side), it can be observed that when the rotational speed increases from 800 rpm to 1000 rpm, the tensile strength value also increases. However, the strength started to slightly decrease at 1200 rpm and above. Meanwhile for Group B (AA7075 at advancing side), the results show an increasing value of tensile strength proportional to rotational speed same trend as in Group A, but abruptly decreased at 1000 rpm, followed by an improvement in tensile strength value at rotational speed of 1200 rpm and 1400 rpm.

All joints fracture at HAZ zone on AA6061 part as proven by previous researchers that claimed the FSW joints basically fractured on the lower strength material side that has minimum hardness value (Amancio-Filho et al., 2008; Koilraj et al., 2012; da Silva et al., 2011).Therefore, the fracture in HAZ zone also proved that seamless joints is achieved in this experiments. For Group A which the advancing side material is AA6061, the tensile strength value is increasing to a maximum at 1000 rpm and start to decrease beyond the 1200 rpm. The maximum UTS were achieved at sample E because higher tool rotation rates will produce higher friction rate and generates higher temperature. Thus, it results in intense mixing of material and the heat supplied is sufficient enough to soften and stir the plasticized materials and smooth consolidation is achieved equally to the retreating side (Dinaharan et al., 2012). Even so, it shows the decrement of tensile strength at further increase in tool rotational speed for Group A. This is due to low heat input, as rotational speed increase up to 1400 rpm and mixing actions in materials become little excessive when tool rotational speed is too high and affects the transportation rate from advancing side to retreating side (Dinaharan et al., 2012). Almost all samples for both groups are defects free welds and produce sound joint except for sample F that has the lowest UTS which is due to surface galling defect (Figure 3F) and tunnel defect (Figure 6b) inside the weldment which contributes to fracture and crack propagation at the defect area.

CONCLUSION

The FSW process of dissimilar aluminium alloys of AA6061 and AA7075 was successfully conducted and the results obtained can be summarized as follows:

1. The surface weld appearance depends on the heat input that corresponded with the rotational speed and material location during the FSW process. The rotational speed of 1000 rpm at positioned AA6061in advancing side for Group A resulted in better surface weld appearance with sound joint and no severe defects.
2. Sample E exhibit maximum tensile strength value of 206.65 MPa with rotational speed of 1000 rpm and with AA6061 positioned at advancing side compared to sample H that positioned AA7075 at advancing side that has minimum tensile strength of 160.28 MPa due to severe defect of tunnel inside weldment and surface galling that contributes to failure.

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